



674

# NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

REPORT NO. 249

## A COMPARISON OF THE TAKE-OFF AND LANDING CHARACTERISTICS OF A NUMBER OF SERVICE AIRPLANES

By THOMAS CARROLL

THIS DOCUMENT ON LOAN FROM THE FILES OF

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS  
LANGLEY AERONAUTICAL LABORATORY  
LANGLEY FIELD, HAMPTON, VIRGINIA



RETURN TO THE ABOVE ADDRESS.

REQUESTS FOR PUBLICATIONS SHOULD BE ADDRESSED  
AS FOLLOWS:

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS  
1724 F STREET, N.W.,  
WASHINGTON 25, D.C.

WASHINGTON  
GOVERNMENT PRINTING OFFICE  
1927



## AERONAUTICAL SYMBOLS

### 1. FUNDAMENTAL AND DERIVED UNITS

	Symbol	Metric		English	
		Unit	Symbol	Unit	Symbol
Length.....	$l$	meter.....	m	foot (or mile).....	ft. (or mi.)
Time.....	$t$	second.....	sec	second (or hour).....	sec. (or hr.)
Force.....	$F$	weight of one kilogram.....	kg	weight of one pound.....	lb.
Power.....	$P$	kg/m/sec.....		horsepower.....	HP.
Speed.....		km/hr.....		mi./hr.....	M. P. H.
		m/sec.....		ft./sec.....	f. p. s.

### 2. GENERAL SYMBOLS, ETC.

$W$ , Weight, $=mg$	$mk^2$ , Moment of inertia (indicate axis of the radius of gyration, $k$ , by proper subscript).
$g$ , Standard acceleration of gravity $=9.80665$ m/sec. <sup>2</sup> $=32.1740$ ft./sec. <sup>2</sup>	$S$ , Area.
$m$ , Mass, $=\frac{W}{g}$	$S_w$ , Wing area, etc.
$\rho$ , Density (mass per unit volume).	$G$ , Gap.
Standard density of dry air, $0.12497$ (kg·m <sup>-4</sup> sec. <sup>2</sup> ) at 15° C and 760 mm $=0.002378$ (lb.-ft. <sup>-4</sup> sec. <sup>2</sup> ).	$b$ , Span.
Specific weight of "standard" air, $1.2255$ kg/m <sup>3</sup> $=0.07651$ lb./ft. <sup>3</sup>	$c$ , Chord length.
	$b/c$ , Aspect ratio.
	$f$ , Distance from $c. g.$ to elevator hinge.
	$\mu$ , Coefficient of viscosity.

### 3. AERODYNAMICAL SYMBOLS

$V$ , True air speed.	$\gamma$ , Dihedral angle.
$q$ , Dynamic (or impact) pressure $=\frac{1}{2}\rho V^2$	$\rho \frac{Vl}{\mu}$ , Reynolds Number, where $l$ is a linear dimension.
$L$ , Lift, absolute coefficient $C_L=\frac{L}{qS}$	e. g., for a model airfoil 3 in. chord, 100 mi./hr. normal pressure, 0° C: 255,000 and at 15° C., 230,000;
$D$ , Drag, absolute coefficient $C_D=\frac{D}{qS}$	or for a model of 10 cm chord 40 m/sec, corresponding numbers are 299,000 and 270,000.
$C$ , Cross-wind force, absolute coefficient $C_c=\frac{C}{qS}$	$C_p$ , Center of pressure coefficient (ratio of distance of $C. P.$ from leading edge to chord length).
$R$ , Resultant force. (Note that these coefficients are twice as large as the old coefficients $L_c, D_c$ .)	$\beta$ , Angle of stabilizer setting with reference to lower wing, $= (i_t - i_w)$ .
$i_w$ , Angle of setting of wings (relative to thrust line).	$\alpha$ , Angle of attack.
$i_t$ , Angle of stabilizer setting with reference to thrust line.	$\epsilon$ , Angle of downwash.



---

## **REPORT No. 249**

---

# **A COMPARISON OF THE TAKE-OFF AND LANDING CHARACTERISTICS OF A NUMBER OF SERVICE AIRPLANES**

**By THOMAS CARROLL**  
**Langley Memorial Aeronautical Laboratory**



## NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

3341 NAVY BUILDING, WASHINGTON, D. C.

---

[An independent Government establishment, created by act of Congress approved March 3, 1915, for the supervision and direction of the scientific study of the problems of flight. It consists of twelve members who are appointed by the President, all of whom serve as such without compensation]

---

CHARLES D. WALCOTT, Sc. D., *Chairman*,  
Secretary, Smithsonian Institution, Washington, D. C.  
DAVID W. TAYLOR, D. Eng., *Secretary*,  
Washington, D. C.  
JOSEPH S. AMES, Ph. D., *Chairman, Executive Committee*,  
Director, Physical Laboratory, Johns Hopkins University, Baltimore, Md.  
GEORGE K. BURGESS, Sc. D.,  
Director, Bureau of Standards, Washington, D. C.  
JOHN F. CURRY, Major, United States Army,  
Chief, Engineering Division, Air Service, Dayton, Ohio.  
WILLIAM F. DURAND, Ph. D.,  
Professor of Mechanical Engineering, Stanford University, Calif.  
EMORY S. LAND, Captain, United States Navy.  
Bureau of Aeronautics, Navy Department, Washington, D. C.  
CHARLES F. MARVIN, M. E.,  
Chief, United States Weather Bureau, Washington, D. C.  
WILLIAM A. MOFFETT, Rear Admiral, United States Navy,  
Chief, Bureau of Aeronautics, Navy Department, Washington, D. C.  
MASON M. PATRICK, Major General, United States Army,  
Chief of Air Service, War Department, Washington, D. C.  
S. W. STRATTON, Sc. D.,  
President, Massachusetts Institute of Technology, Cambridge, Mass.  
ORVILLE WRIGHT, B. S.,  
Dayton, Ohio.

### EXECUTIVE COMMITTEE

JOSEPH S. AMES, *Chairman*.  
DAVID W. TAYLOR, *Secretary*.  
GEORGE K. BURGESS. MASON M. PATRICK.  
JOHN F. CURRY. S. W. STRATTON.  
EMORY S. LAND. CHARLES D. WALCOTT.  
CHARLES F. MARVIN. ORVILLE WRIGHT.  
WILLIAM A. MOFFETT.  
GEORGE W. LEWIS, *Director of Aeronautical Research*.  
JOHN F. VICTORY, *Assistant Secretary*.



## REPORT No. 249

### A COMPARISON OF THE TAKE-OFF AND LANDING CHARACTERISTICS OF A NUMBER OF SERVICE AIRPLANES

By THOMAS CARROLL

#### SUMMARY

This investigation, which is a continuation of Technical Report No. 154, "A Study of Taking Off and Landing an Airplane" (Reference 1), follows very closely the earlier methods and covers a number of service airplanes, whereas the previous report covered but one, the JN-4h.

In addition to the air speed, acceleration, and control positions as given in Report No. 154, information is here given regarding the distance run and the ground speed for the various airplanes during the two maneuvers.

#### INTRODUCTION

It was stated in Technical Report No. 154 that little attention had been given to taking off or landing. While the performance of the airplane as to speed, climb, ceiling, and to a certain extent also as to controllability, maneuverability, and stability, is subject to a quantitative analysis, the maneuver of taking off or landing is difficult to evaluate, because it is dependent upon the pilot's ability, the power plant, and weather and field conditions. Variations arising from differences in the skill of the pilot are not considered in this report, and an attempt has been made to reduce all of the maneuvers to average landings or take-offs.

Complete records of a number of flights were obtained on each of the airplanes investigated, and only records of good average grade, free from extraneous influences, were selected for consideration. The results are given in one form in Table I to show the relation of the various factors which enter into the maneuver for each airplane, and again in Tables II and III in forms from which comparisons may readily be made among the different types investigated.

The procedure followed was identical with that described in Technical Report No. 154, with the addition of evaluations of the ground speeds and distances of ground run. Each of the landings was made from a straight glide directly into the wind, using the best available portion of the landing field. The throttle was tightly closed and the idling adjustment was normally slow. In the take-off the throttle was opened fully in the shortest possible time commensurate with good practice, and the take-offs were accomplished in a modified tail-high position. This is at variance with the practice of a prolonged maintenance of the tail-high position recommended in Report No. 154, and was made necessary by the poor condition of the landing field at Langley during the time these tests were in progress. However, such a modified take-off is considered to be in accordance with average practice.

#### AIRPLANES INVESTIGATED

Curtiss JN-6h.  
Vought VE-7.  
DH-4b.  
Fokker CO-4.  
SE-5a.

SPAD-VII.  
Thomas-Morse MB-3.  
Martin Bomber MB-2.  
Sperry Messenger.



Several pilots assisted in securing the data of this report, but all the flights recorded were made by the pilots of the committee's staff with the exception of those on the Martin Bomber MB-2, which were made by a service bomber pilot. An average of 10 complete records was obtained on each airplane in the two maneuvers under investigation.

#### INSTRUMENTS AND INSTALLATION

The instruments used were, with one exception, identical with those employed in the earlier work, and were of the recording type as developed at the laboratory of the National Advisory Committee at Langley Field. These instruments comprised the following:

(1) N. A. C. A. control position recorder (Reference 2). This instrument was attached directly to the control cables in the fuselage. Slight errors may be seen in the records, which were due largely to slack in the controls. A precision of plus or minus 10 per cent was obtained.

(2) The N. A. C. A. accelerometer (Reference 3), which measured the acceleration during the maneuvers and also located definitely the instant at which the ground contact was made or broken.

(3) The N. A. C. A. air-speed recorder (Reference 4), equipped with the universal swiveling Pitot head, as developed at the laboratory. This was used for measuring the air speed with an accuracy of plus or minus 3 per cent.

The fourth instrument used was a specially designed and constructed ground-speed recorder which has not been described previously. This recorder consisted of a small air compressor attached to the stationary axle of the chassis and actuated by a plunger which was depressed by an eccentric race or cam attached to the side of the airplane wheel. Each impulse of this compressor was transmitted by a tube to one side of a diaphragm instrument of the usual recording type and represented one revolution of the wheel. Thus the distance of the roll was obtained by multiplying the number of such recorded revolutions by distance obtained by rolling the wheel one revolution under full load and on a flat surface. Many records indicated that the wheel began to turn either slightly before or shortly after impact with the ground. This was accounted for in the first instance by the dragging of the wheel over high grass or weeds, and in the second by a very small slippage over smooth or soft ground. Correction was made by using the accelerometer record as indicating the true point of contact. As a further check several ground runs were measured by chain, and no appreciable error in the records was found. The individual records may be taken as correct within plus or minus 20 feet.

All of the instruments were synchronized through a chronometric timer, which produced a vertical line across the moving film at regular intervals to provide a basis for the correlation of all the records. A single electric switch in the cockpit controlled all the instruments.

#### RESULTS

The records obtained for each of the airplanes are shown in Figures 1 to 9a. These show the air speed, ground speed, ground-run distance, acceleration, and position of all controls throughout the maneuver, plotted against time.

Table I gives a recapitulation of the results reduced to zero wind speed.

The first inspection of the data may be somewhat confusing, due to the difference between instrumental records and visual impressions, since it usually appears to the casual observer that a large airplane flies and lands very slowly and a small one lands very fast. From casually observing a number of airplanes landing it is difficult for an untrained observer to believe that a Martin Bomber and a Thomas-Morse pursuit airplane land at about the same speed, or that a Martin Bomber lands about 15 miles faster than a Sperry Messenger. Of course the landing speed varies as the square root of the wing loading and inversely as the maximum lift coefficient, but we are now concerned with the impressions obtained by casual observation.

The weights given are the actual weights as measured with the airplane ready for flight. No attempt was made to run at the full military load, but the weights given will indicate the proportion of load which each airplane carried. These weights did, however, include a full crew for each airplane.



Figures 10 and 11 present the method of reducing the data to a condition of zero wind speed by plotting the various ground distances observed against the various wind velocities at the ground at the time the record was taken. Assuming that an airplane landing in a wind of a velocity equal to its landing speed has zero ground run, a fair curve was drawn through the point on the ordinate axis representing the landing speed and the group of observed points. The intersection of this curve with the base line indicates the ground run at zero wind speed. Since the observed points are usually at low wind speeds, the error can not be large. These figures present valuable information as to the ground run which may be expected of any of these various types of airplanes in winds up to and including their landing speeds. The manner of approach should not change the landing speed, which is definite for any airplane with a constant weight. The ground run is dependent on landing speed and wind velocity and is independent of the method of approach.

## CONCLUSION

It is hoped that the results presented will prove of value to pilots in considering the ground maneuvers of certain airplanes, particularly in regard to the runway required to take-off or land under various conditions of wind speed; or to others in estimating the proper size for proposed landing fields, etc. It is recommended that further work be done covering those phases of taking off and landing which are not definitely tied up with the performance of the airplane; that is, the effect in approaching a landing in "side-slip," in "fish-tailing," or in making use of the available side winds, which permits setting the airplane down in a more confined space. This information in conjunction with the present report and report No. 154 would cover these maneuvers comprehensively.

TABLE I

	Weight, pounds	Wing load- ing, lb. / sq. ft.	Nominal power loading lb. / HP.	Take-off run, feet	Take-off air speed M. P. H.	Landing run, feet	Landing air speed M. P. H.	Angle of attack of wings on ground, degrees
SE-5a.....	2,080	8.67	11.5	300	53	450	54	14
JN-6h Curtiss.....	2,767	7.85	18.5	410	48	575	51	13.2
SPAD-VII.....	1,625	8.40	9.0	315	58	485	58	15.4
VE-7 Vought.....	2,152	7.57	12.0	275	50	800	51	12.7
DH-4b.....	4,000	9.10	10.0	340	51	725	56.5	12.3
CO-4 Fokker.....	4,155	10.10	10.4	380	52	950	56	11
Sperry Messenger.....	965	6.5	16.0	320	42	400	44	17.2
MB-3 Thomas-Morse.....	2,277	9.63	7.6	325	57	875	57	15
MB-2 Martin Bomber.....	10,520	9.7	13.2	585	63	925	58	13

TABLE II

COMPARATIVE SPEEDS AND DISTANCES OF TAKE-OFFS

	Speed, M. P. H.	Distance, feet
1. Sperry Messenger.....	42	310
2. JN-6h Curtiss.....	48	390
3. VE-7 Vought.....	50	275
4. DH-4b.....	51	340
5. CO-4 Fokker.....	52	382
6. SE-5a.....	53	300
7. SPAD-VII.....	58	315
8. MB-3 Thomas-Morse.....	58	325
9. MB-2 Martin Bomber.....	63	550



TABLE III  
COMPARATIVE SPEEDS AND DISTANCES IN LANDINGS

	Speed, M.P.H.	Distance, feet
1. Sperry Messenger.....	44	400
2. JN-6h Curtiss.....	51	575
3. VE-7 Vought.....	51	800
4. SE-5a.....	54	450
5. MB-3 Thomas-Morse.....	56	875
6. CO-4 Fokker.....	56	950
7. DH-4b.....	56.5	725
8. SPAD-VII.....	58	485
9. MB-2 Martin Bomber.....	58	925

## REFERENCES

1. CARROLL, T. A Study of Taking Off and Landing an Airplane. N. A. C. A. Technical Report No. 154, 1922.
2. NORTON, F. H. N. A. C. A. Control Position Recorder. N. A. C. A. Technical Note No. 97, May, 1922.
3. NORTON, F. H., and BROWN, W. G. The Pressure Distribution Over the Horizontal Tail Surfaces of an Airplane, III, 1922.
4. NORTON, F. H. N. A. C. A. Recording Air Speed Meter. N. A. C. A. Technical Note No. 64, October, 1921.

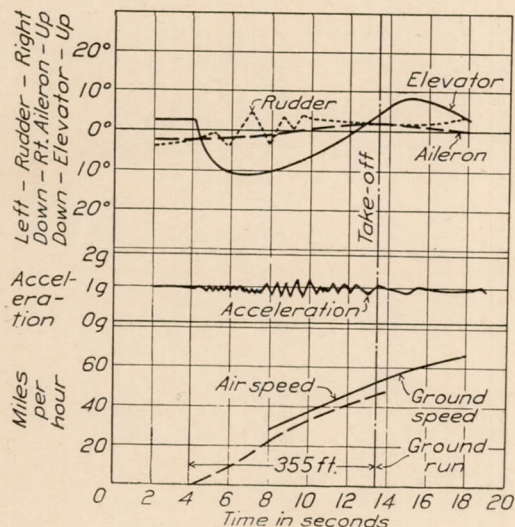


FIG. 1.—Take off. CO-4

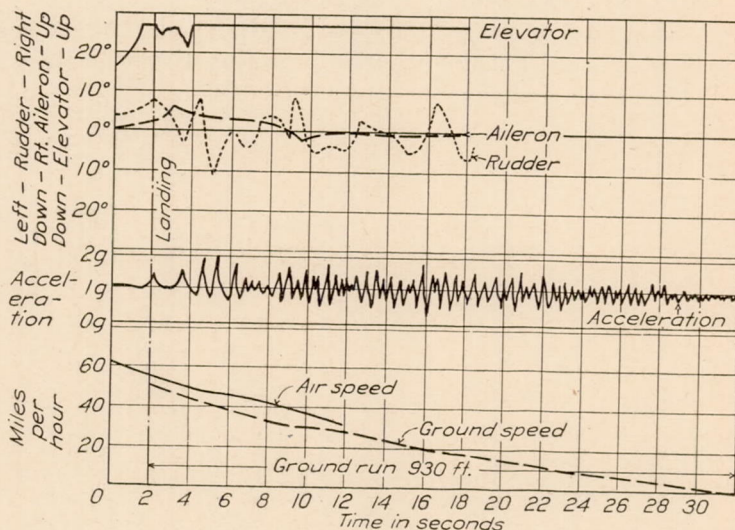


FIG. 1a.—Landing. CO-4

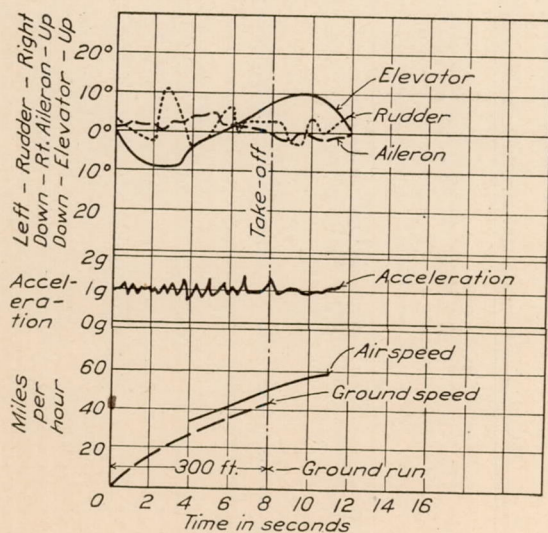


FIG. 2.—Take off. DH-4b

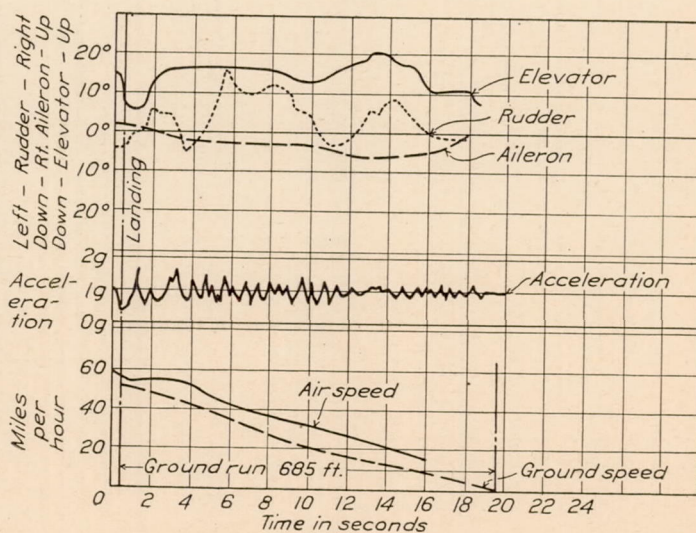


FIG. 2a.—Landing. DH-4b



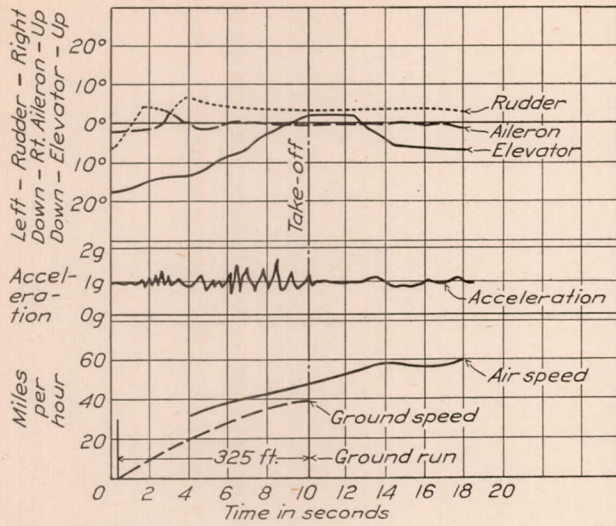


FIG. 3.—Take off. JN-6h

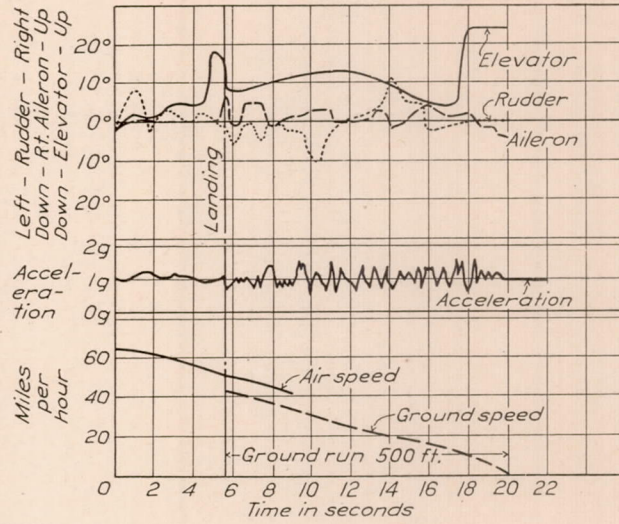


FIG. 3a.—Landing. JN-6h

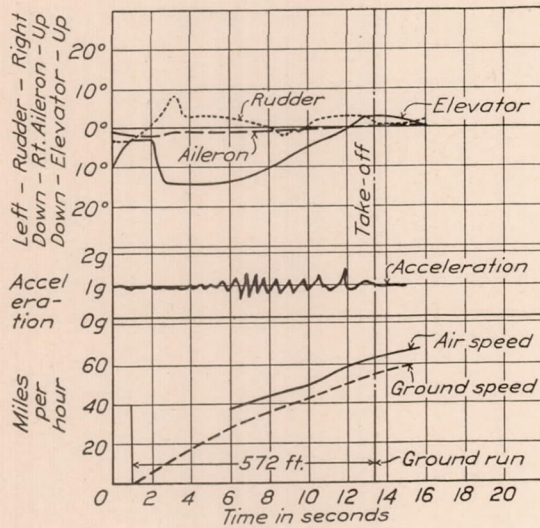


FIG. 4.—Take off. MB-2

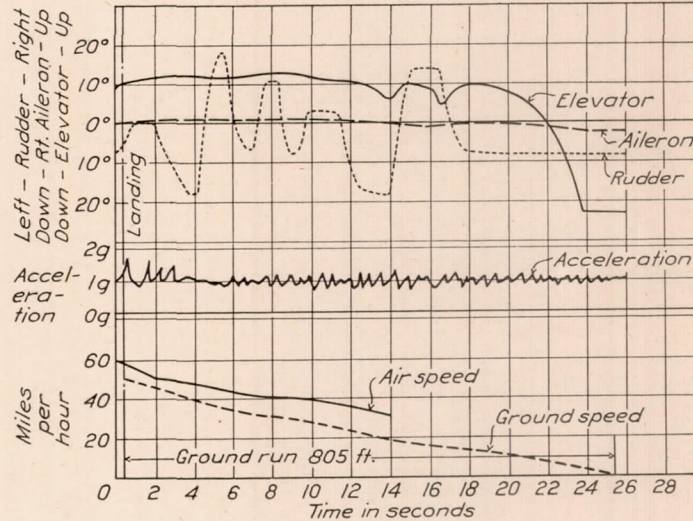


FIG. 4a.—Landing. MB-2

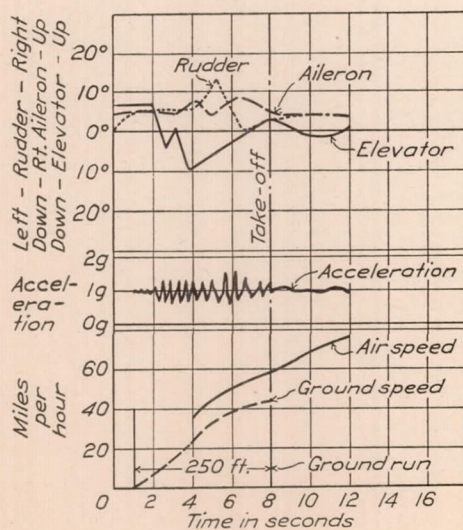


FIG. 5.—Take off. MB-3

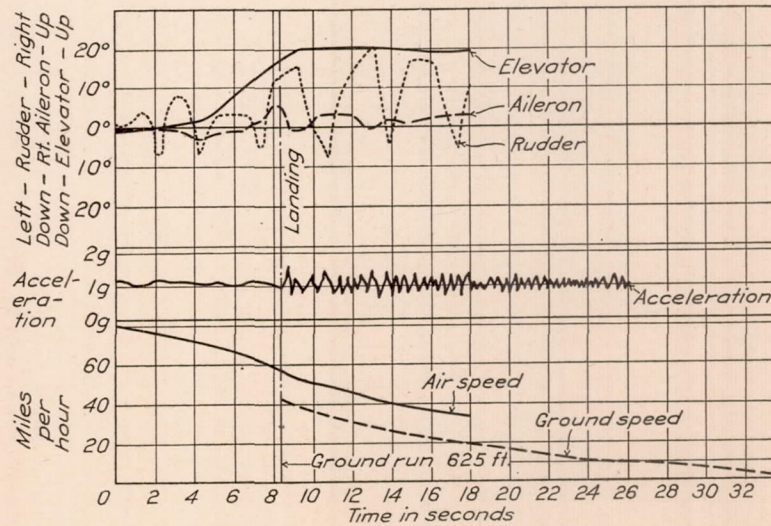


FIG. 5a.—Landing. MB-3



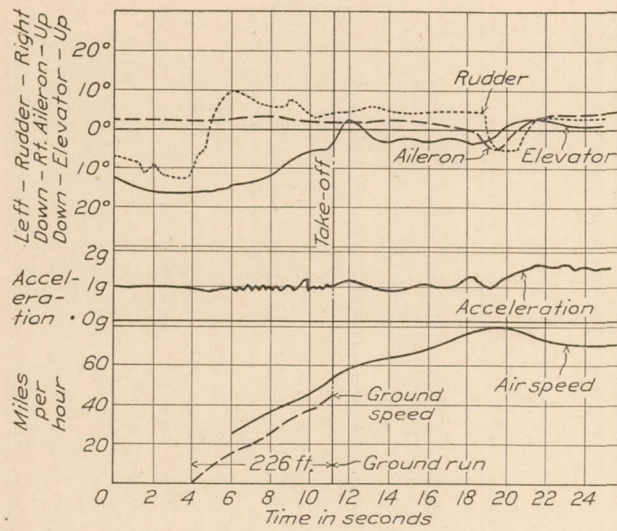


FIG. 6.—Take off. SE-5a

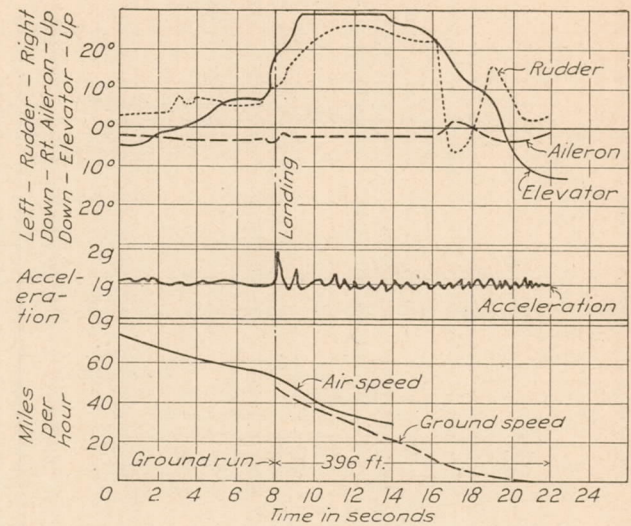


FIG. 6a.—Landing. SE-5a

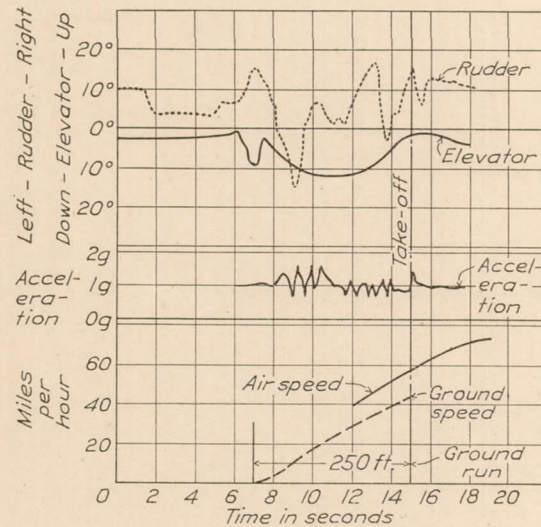


FIG. 7.—Take off. SPAD-VII

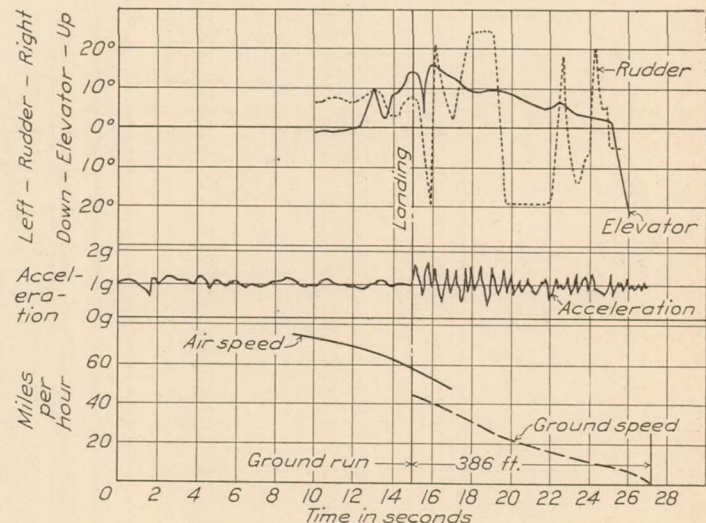


FIG. 7a.—Landing. SPAD-VII

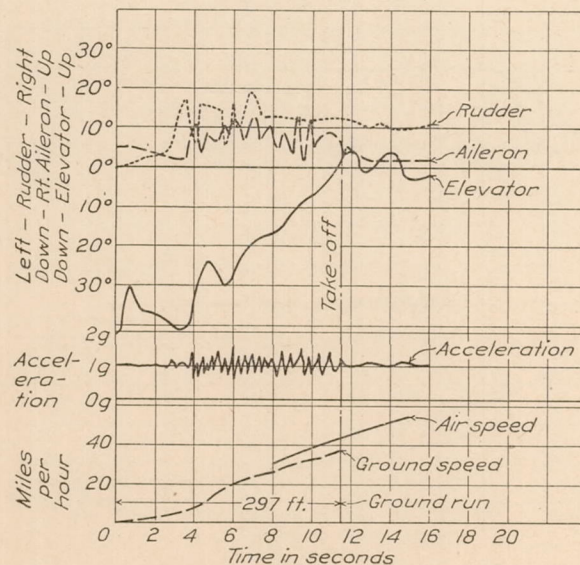


FIG. 8.—Take off. Sperry Messenger

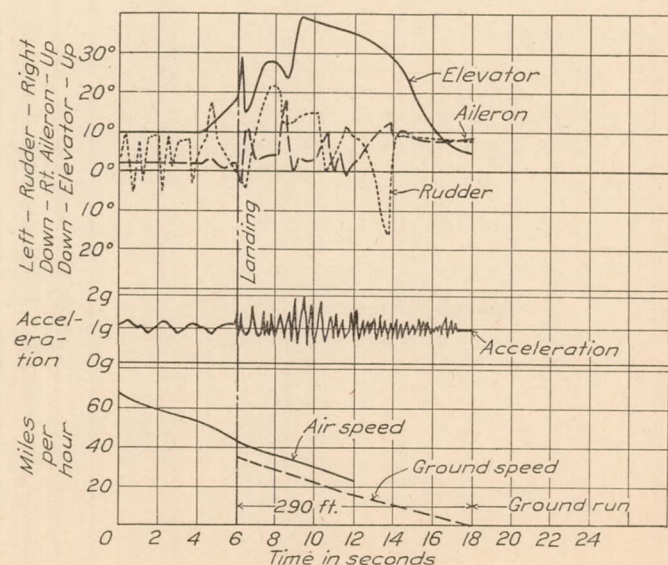


FIG. 8a.—Landing. Sperry Messenger



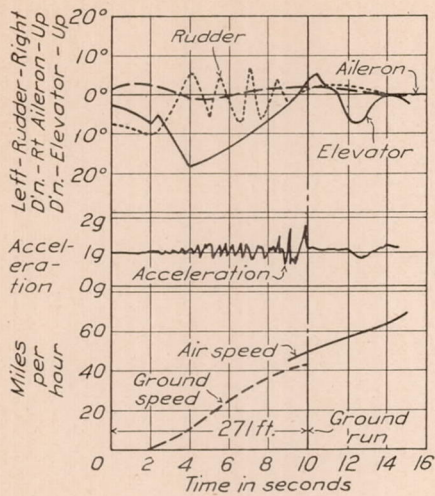


FIG. 9.—Take off. VE-7

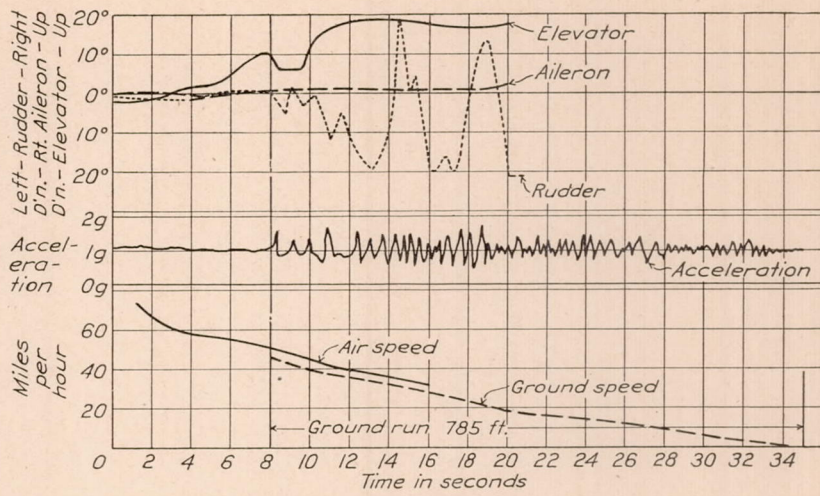


FIG. 9a.—Landing. VE-7

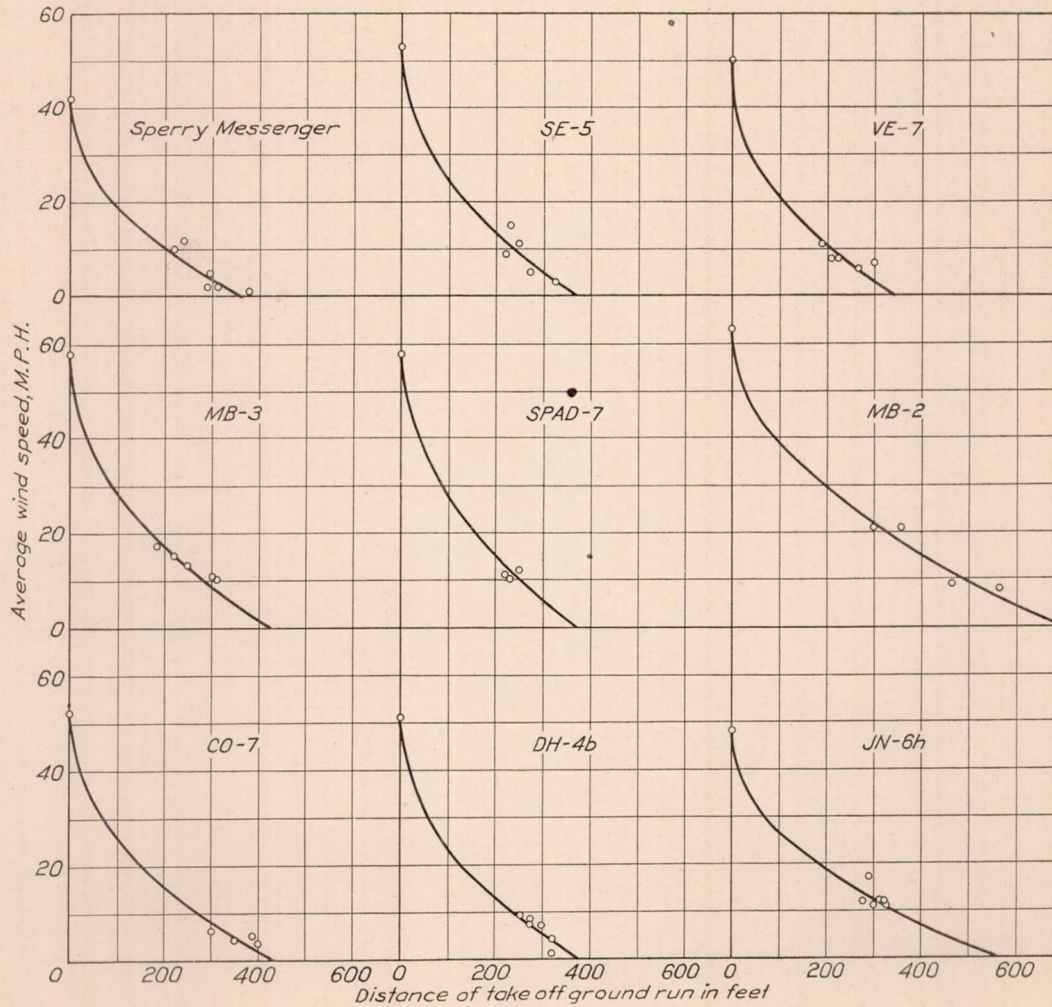


FIG. 10.—Take-off ground run versus wind speed



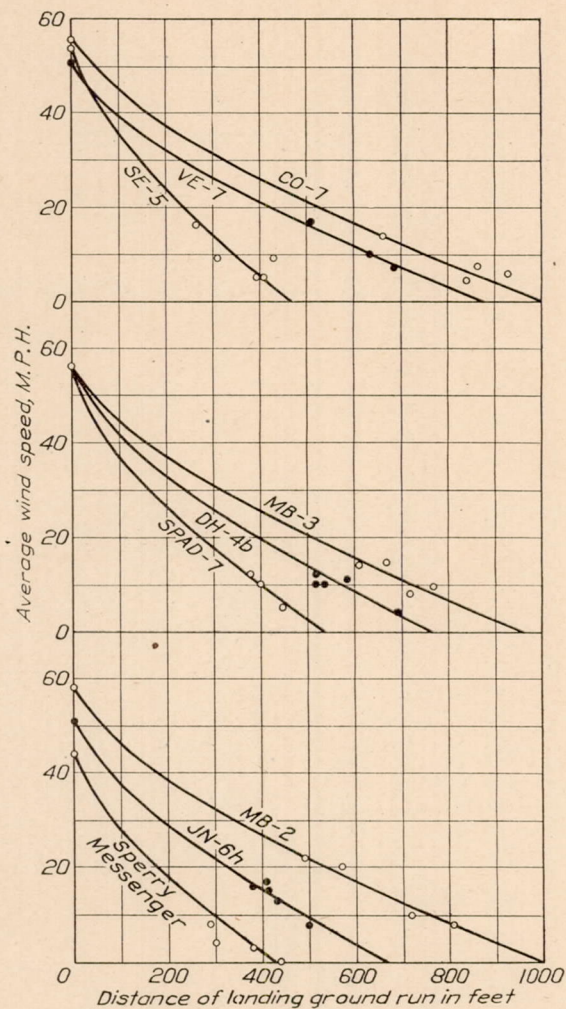


FIG. 11.—Landing ground run versus wind speed

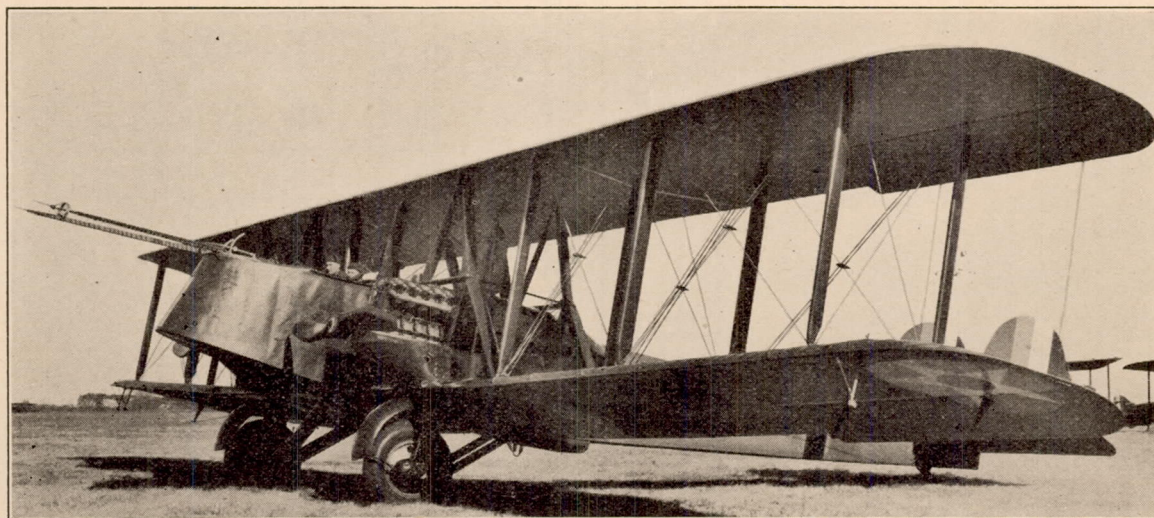


FIG. 12.—Martin Bomber MB-3 ready for landing and take-off tests, showing installation of air-speed head. (NOTE.—The second boom carried and angle-of-attack instrument which was not used in all tests)



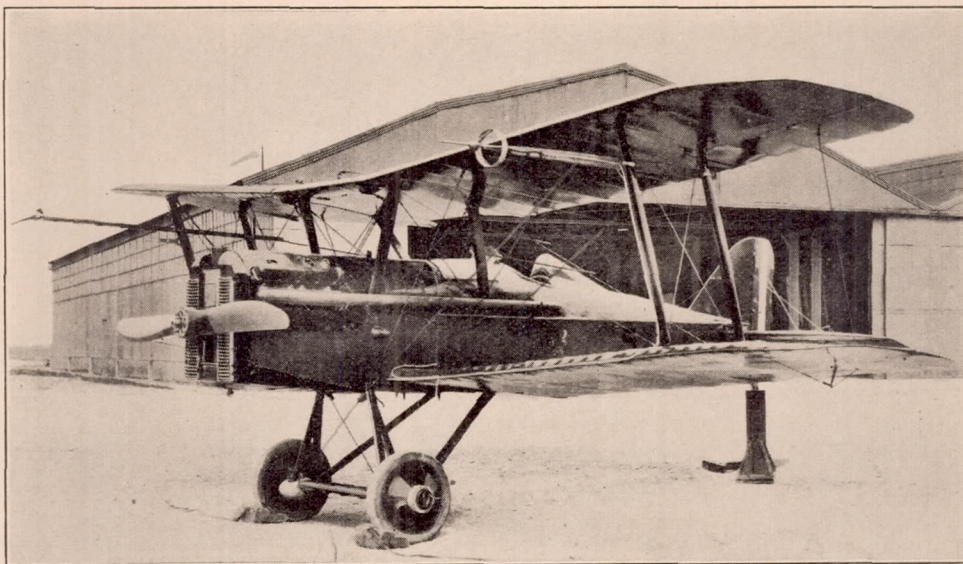


FIG. 13.—SE-5a airplane as prepared for landing and take-off tests, showing ground-speed recorder on wheel, air-speed head on left strut, and angle-of-attack instrument on right. (NOTE.—The angle-of-attack instrument was not used in all tests)

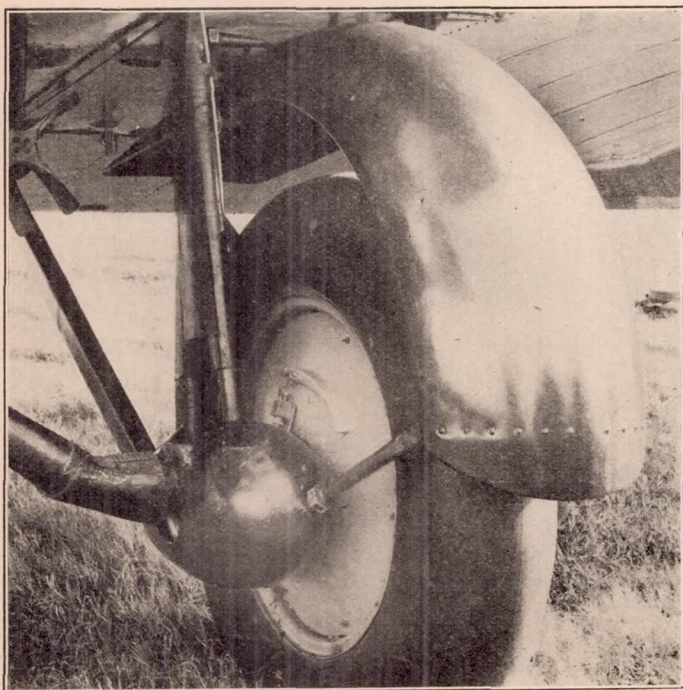
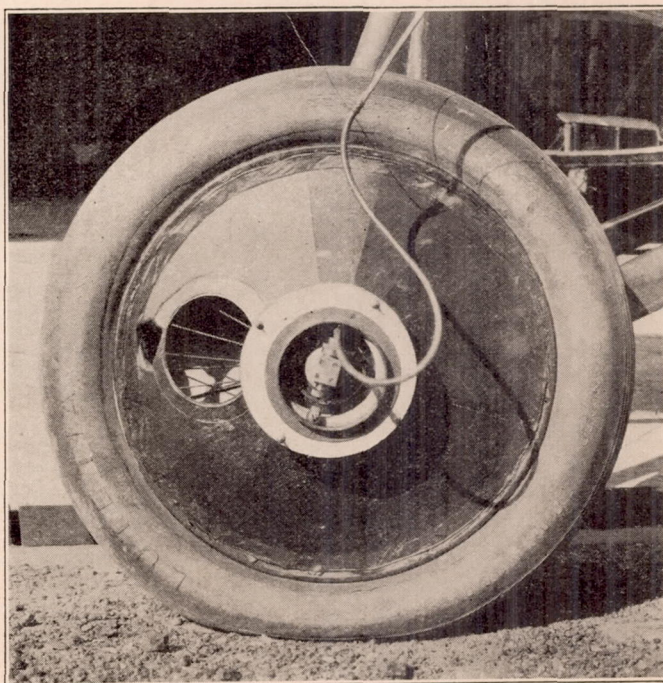


FIG. 14.—Ground-speed recorder installed on Martin Bomber MB-2, showing cam attached to wheel fairing



FIG' 15.—Ground-speed recorder on wheel of SE-5a



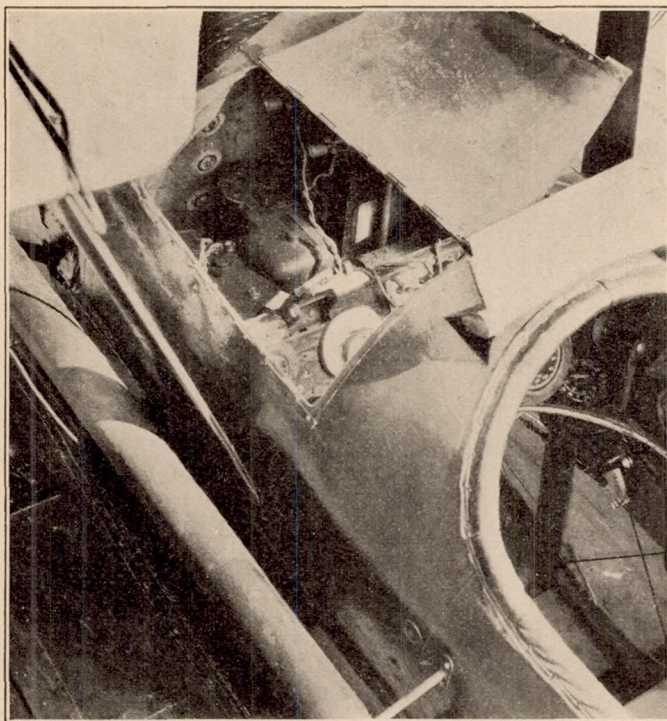


FIG. 16.—Instruments and battery installed in cockpit of SE-5a.

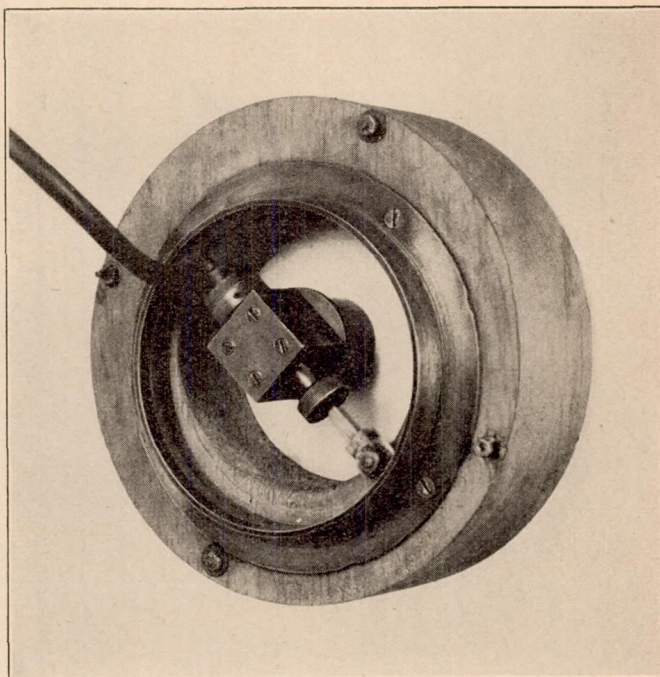


FIG. 17.—The ground-speed recorder showing eccentric race, as installed on all airplanes except the Martin Bomber MB-3

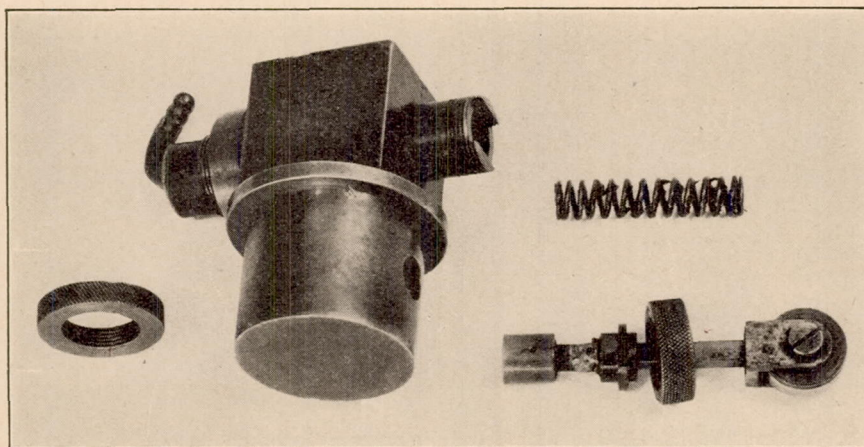
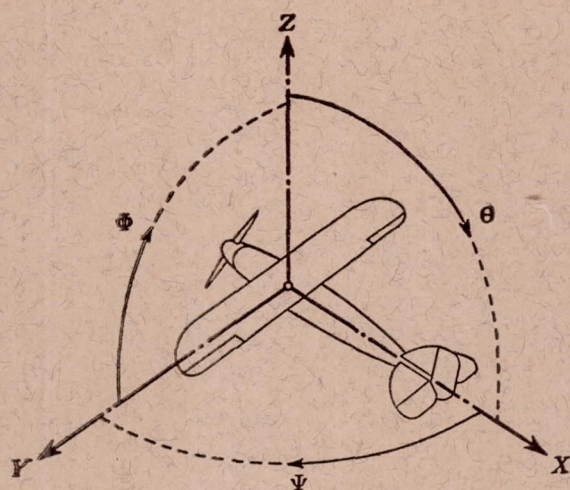


FIG. 18.—The ground-speed recorder disassembled

ADDITIONAL COPIES  
OF THIS PUBLICATION MAY BE PROCURED FROM  
THE SUPERINTENDENT OF DOCUMENTS  
GOVERNMENT PRINTING OFFICE  
WASHINGTON, D. C.  
AT  
10 CENTS PER COPY  
▽





Positive directions of axes and angles (forces and moments) are shown by arrows

Axis		Force (parallel to axis) symbol	Moment about axis			Angle		Velocities	
Designation	Sym- bol		Designa- tion	Sym- bol	Positive direction	Designa- tion	Sym- bol	Linear (compo- nent along axis)	Angular
Longitudinal	X	X	rolling	L	Y → Z	roll	Φ	u	p
Lateral	Y	Y	pitching	M	Z → X	pitch	Θ	v	q
Normal	Z	Z	yawing	N	X → Y	yaw	Ψ	w	r

Absolute coefficients of moment

$$C_L = \frac{L}{qbS} \quad C_M = \frac{M}{qcS} \quad C_N = \frac{N}{qfS}$$

Angle of set of control surface (relative to neu-  
tral position),  $\delta$ . (Indicate surface by proper  
subscript.)

#### 4. PROPELLER SYMBOLS

$D$ , Diameter.

$p_e$ , Effective pitch

$p_g$ , Mean geometric pitch.

$p_s$ , Standard pitch.

$p_v$ , Zero thrust.

$p_a$ , Zero torque.

$p/D$ , Pitch ratio.

$V'$ , Inflow velocity.

$V_s$ , Slip stream velocity.

$T$ , Thrust.

$Q$ , Torque.

$P$ , Power.

(If "coefficients" are introduced all  
units used must be consistent.)

$\eta$ , Efficiency =  $T V/P$ .

$n$ , Revolutions per sec., r. p. s.

$N$ , Revolutions per minute., R. P. M.

$\Phi$ , Effective helix angle =  $\tan^{-1} \left( \frac{V}{2\pi r n} \right)$

#### 5. NUMERICAL RELATIONS

1 HP = 76.04 kg/m/sec. = 550 lb./ft./sec.

1 kg/m/sec. = 0.01315 HP.

1 mi./hr. = 0.44704 m/sec.

1 m/sec. = 2.23693 mi./hr.

1 lb. = 0.4535924277 kg.

1 kg = 2.2046224 lb.

1 mi. = 1609.35 m = 5280 ft.

1 m = 3.2808333 ft.



